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Norman Metzger has made a comprehensive challenge to the role of economists and the possibility of quantifying the benefits from high-energy physics. I want to begin on a note of agreement before I examine our disagreements.

Like Metzger, I also believe that it is incorrect to try to come to a single measure of the final benefit of high-energy physics, or any other basic research program, to the gross national product. As a nation, however, we are re-evaluating the role of our federal government and its expenditures. This re-evaluation is not the sort that occurs with each new administration, but instead is one that asks what is the role of federal expenditures, federal taxation, and federal debt in order to plan the future economic life of our nation.

The U.S. scientific community has been blessed by 40 years of public confidence and generosity. In good times and bad, the federal government has been the major source of funding for research aimed at exploring and enlarging the frontiers of scientific knowledge. This support from public funds is a direct consequence of the belief that more scientific knowledge eventually makes the world a better place in which to live. And a primary measure of making the world a better place in which to live is increasing economic prosperity.

Recently, the social consensus about the value of science to the economy has been strained. Thus, I think that it is apt at this time that we begin to more closely examine the connections between basic research and technology, between scientific knowledge and technological application of that knowledge, and, further, what impact those improvements and technological capability have on our capacity to do new scientific research.

In the hope of resolving some of these problems, some of my colleagues at the Stanford Center for Economic Policy Research have founded a program called the High Technology Impact Program. The research goal of this program is to provide better measures of the contribution of technological change to economic growth and prosperity. We have focused on the under-appreciated role that technological improvements in upstream industries such as electronic components, scientific instruments, and computers have had in downstream industries and on consumers. In addition, each of us has been concerned for some time with the inadequacy of economic understanding of technological innovation. Part of the reason that there are inadequacies in the current economic understandings of these problems is that there has been insufficient attention on the part of the economics profession to the role of science and technology in innovation when considering questions of science and technology policy. In particular, economics has to date provided little insight into issues such as the role of basic research on long-term economic growth, the trade-offs involved in research contracting, the interactions between basic and applied research, the organizational and incentive issues of how research can most efficiently be organized, and methods to accelerate technology transfer, either from or to federal research facilities.

Early in our research effort we determined that the greatest contributions to be made currently would come from very specific studies of particular industries and technologies. While better general models are needed, they need to grow out of a strong fact base and the sort of detailed case studies and anecdotal base that Metzger had mentioned.

Recently we were asked what economists might be able to say about the economic impacts of high-energy physics research. After some thought, we wrote a proposal outlining some of the avenues for research. I would like to share a brief overview of that proposal with you today.

Our first finding was that economists in the U.S. have never systematically examined high-energy particle physics, which I'll refer to as "HEP." This is indicative of a problem in my profession: too much theory untested by detailed knowledge. Our second finding was that this was going to be a difficult undertaking. The fundamental problem was to separately consider the outcomes of scientific research, and the process by which these outcomes or results are achieved. Our intuition and our working hypothesis is that the *process* of HEP research generates important economic impacts more rapidly than the fundamentally new, and often revolutionary, insights that are the content of HEP research *results*. We were delighted to find that several European researchers had reached similar conclusions. In an economic study of CERN suppliers, major economic benefits were identified. The source of these benefits were technologies developed or improved upon in order to *conduct* HEP research.

We also found that Leon Lederman had provided Congress with a specific list of commercial applications of HEP research outcomes. So, our initial research goals include enumerating technologies that have been affected by the HEP research process or its outcomes. This research goal can be attained with the assistance of the industries represented here today. Such research is both an anecdotal process and the beginnings of data-gathering. If we were to stop with a collection of anecdotes and examples, we would only be providing a larger store of such examples. This is a useful task, but one which fails to quantify the benefits. Quantification of benefits is necessarily an exploratory effort, one which does not result in a single number. Through a series of examples, quantification provides concrete evidence to show where high-energy physics research has had an economic impact on society. The process of quantification can then serve as a guide for further research into the linkages between basic research and its economic connection to growth and prosperity.

In order to begin the process of quantifying these benefits, we considered two methodologies. The first is illustrated in Fig. 1. In this illustration there is a theoretical demand curve that I'll discuss a little more in a moment. This figure illustrates the principle of consumer surplus which is a well-accepted measure of economic benefit.

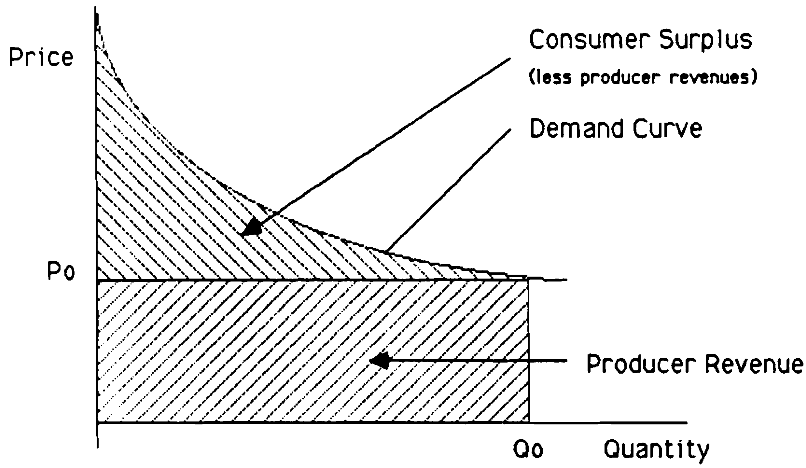
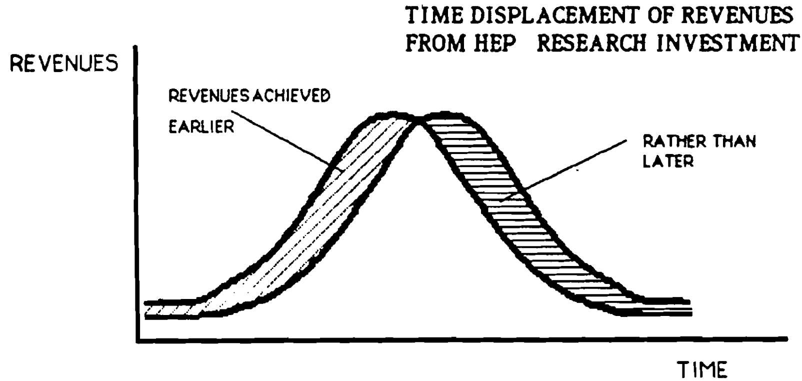


Figure 1

Consumer surplus is simply the difference between what consumers would be willing to pay for a given quantity of a good and what they actually have to pay. In this case, the price that consumers are paying in this market is represented by the number P0. The area above P0 and beneath the demand curve, shaded by diagonal lines falling to the right, is the consumer surplus. Consumer surplus is a measure of what purchasers would have been willing to pay for a product The amount they actually pay is the area of the rectangle beneath P0 and extending to Q0. Measurement of consumer surplus is one method for quantifying the benefits of a specific product. It assumes that we can understand the demand for a product and the value that purchasers place on price-performance improvements. To count this value as a benefit of HEP, we must settle some of the attribution problems that Metzger mentioned, including the question of what the allocation between federal and private research expenditures should be in attributing this consumer surplus. Suppose that, in the process of conducting HEP research, it is necessary to improve a commercially available technology. The "spillover" from HEP research is then a reduction in the price of this technology when it is sold to commercial purchasers. The benefit of this price reduction is measured by the consumer surplus generated by the price reduction. The above discussion and accompanying figure examine the case of a product that would not exist without HEP research.

The same methodology can also be used for products which were simply improved by the existence of HEP research effort. These are products where the price and performance of the product were improved over what they might have been without the benefits of research. I want to stress that this is a technique that requires a great deal of care and specificity in its application and that it is going to be necessary to look at technologies in which HEP research has had a role at a very detailed and specific level. Therefore, it is not going to have any prospect of establishing a general, single number for the contribution of HEP research to the economy. On the other hand, it is a principal technique for coming to some very concrete conclusions and providing some empirical content to the anecdotal information. If we only had anecdotal information without any reference to its quantitative significance, we would always be asked, "Well, is this significant?" This is my primary discomfort with the view presented by Norman Metzger.

Consumer surplus measurement is one of the two techniques that our preliminary research has indicated would be useful. The second is illustrated in Fig. 2 [page 35], and is a somewhat simpler technique that I have applied to the measurement of benefits from the satellite research that was done by the federal government. In many people's opinion this research accelerated the rate of application of telecommunication satellites.



CURVES DEPICT THE PRODUCT CYCLE FOR A PRODUCT BASED ON HEP RESEARCH

Figure 2

This figure depicts two product cycles. They are both for the same product and the only difference is that the existence of HEP research, or any other federal research program, has accelerated, or brought forward in time, a revenue stream that would have been delayed without federal support of research. The contribution of public research expenditure is measured by the difference of present values of the two revenue streams. The one that occurs earlier, of course, has a higher present value. Such methods can be used to approximate the benefits from high-energy physics research in a specific area. Again, in terms of putting together a specific case study where the level is quantified, this technique can also be useful.

I want to stress that these two quantification methods can only work if we are able to gather and critically evaluate information from industry. I hope that we can cooperate with industry on this research which I believe can go a long way toward helping rebuild a consensus about the value of HEP research.

The last issue I want to briefly mention is the issue of research organization. HEP research and the Universities Research Association are important and unique models for the federal support of basic research. Our proposed research intends to examine some of the benefits, and perhaps limitations, of this form of organization including its role in technology transfer both from and to national research efforts. On balance, the Universities Research Association is an extremely interesting model of cooperation between federal laboratories, university departments, and contractors. We hope to learn more about this effort from both administrators and contractors.